Observations and trends of emissions from gas flaring in the Persian Gulf region using OMI

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Introduction on Gas Flaring

- Gas flaring: a method to dispose the gases associated with petroleum for safety, operational and economic reasons.
  - $10 billion/yr loss, ~5% of the global natural gas product
  - 400 Mt/yr CO_2 emissions (2% of the global emissions from energy sector), equivalent to 77 million cars or 125 medium-size power plants
  - Sources of air pollutants: CH_4, CO_2, CO, H_2S, SO_2, NO_x, BC, VOCs, heavy metals, etc.

- Emission Factor (EF): ratio of gas flared per barrel of oil produced (Unit: m^3 /barrel). Global average EF is 5 m^3/barrel, but ranges from ~1.0 in the U.S, ~8.0 in Iran, ~10.0 in Russia, to ~50 in Uzbekistan.

A North Sea oil-drilling platform with natural gas "flare off" , adapted from http://www.britannica.com/bps/media-view/95739/1/0/0

World Bank GGRF datasets

GGRF data are estimates based on DMSP-OLS and MODIS satellite measurements. The night-time lights from gas flares observed by the satellites provide an estimate of the amounts of gas flared.

Figure 6. Color composite of the nighttime lights of the Nigeria region generated using 1994 as blue, 2000 as green, and 2008 as red. The colors of the flares indicate their activity patterns during the three years used in the color composite. Note the six red offshore flares, indicating the increase in offshore oil production in 2008 relative to 2000 and 1994. The vector polygon drawn around the gas flares of Nigeria is shown in yellow. The diffuse light in the upper right is from biomass burning.

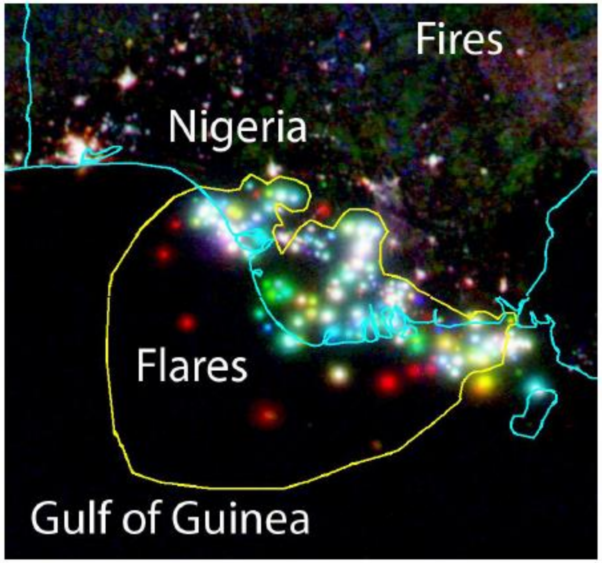
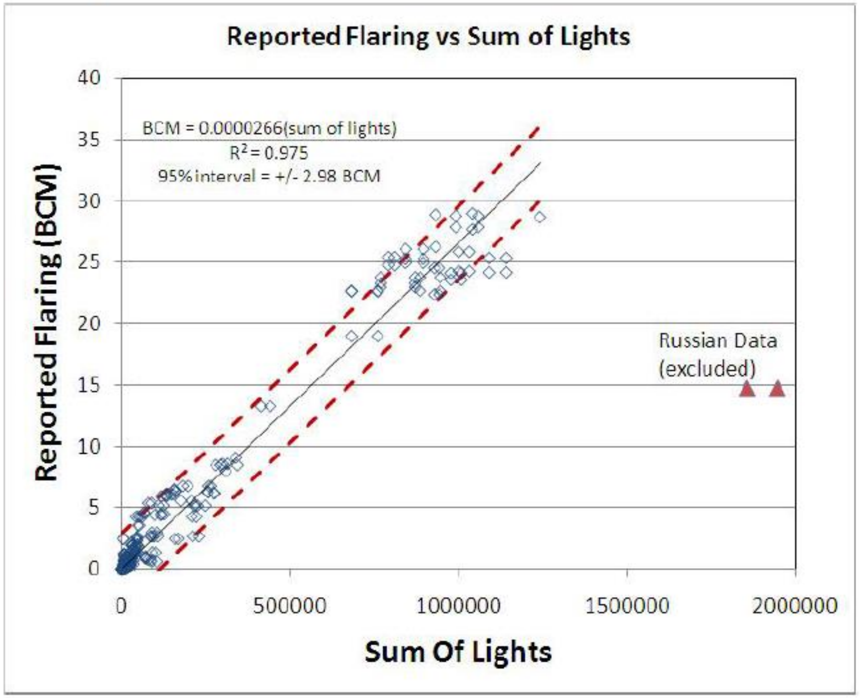


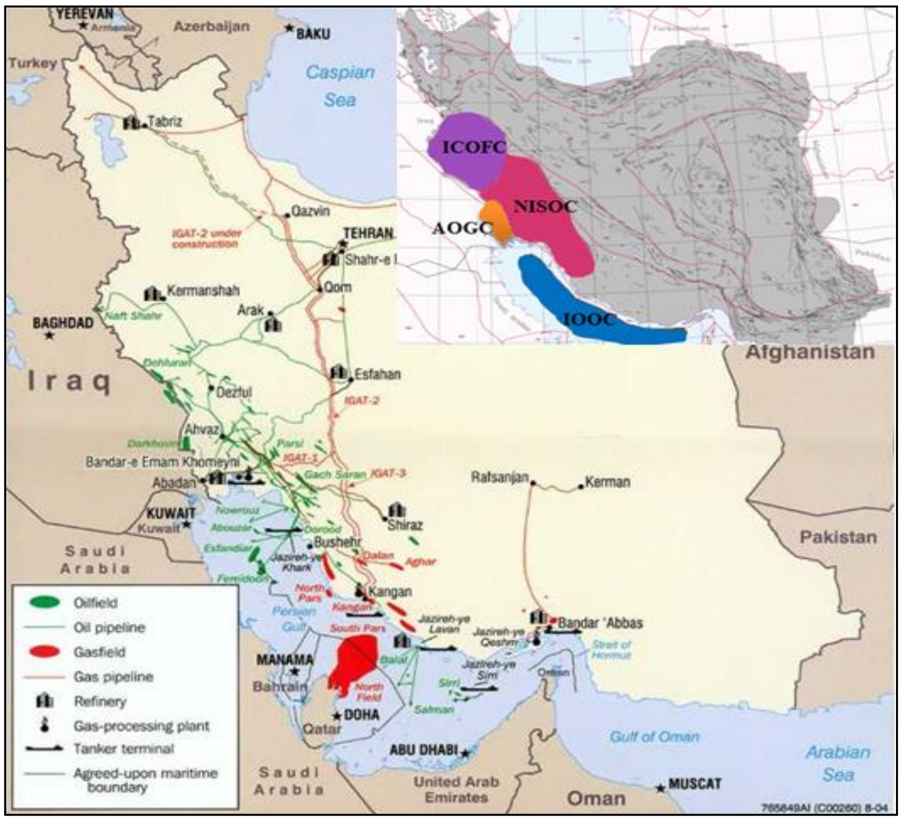
Figure 8. Plot of the reported BCM levels of flared gas versus the sum of light index, regression line (solid line) and 95% prediction intervals for individual BCM estimates (dashed red lines).

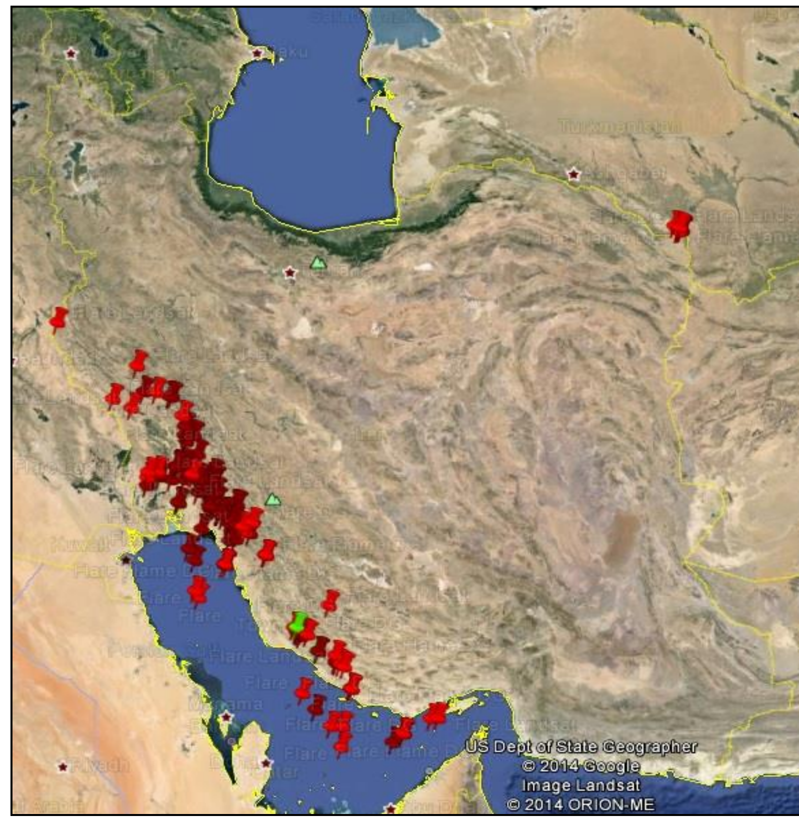


C. Elvidge, D. Ziskin, K. Baugh, B. Tuttle, T. Ghosh, D. E. E. Pack and M. Zhizhin, "A Fifteen Year Record of Global Natural Gas Flaring Derived from Satellite Data," Energies, pp. 595-622, 2009.

Gas Flaring In Iran

- Iran is the 3rd largest gas flaring country after Russia and Nigeria, with ~14×10^{9} m^{3}/yr gases flared, ~8% of the global flaring.





Oil & Gas production and Flaring maps

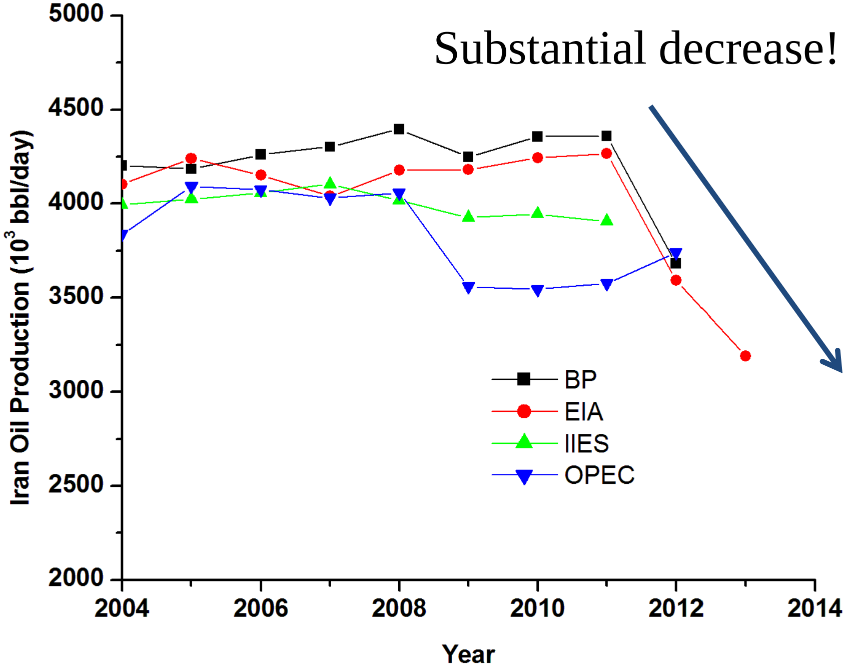
Gas Flaring Emissions from Offshore Fields

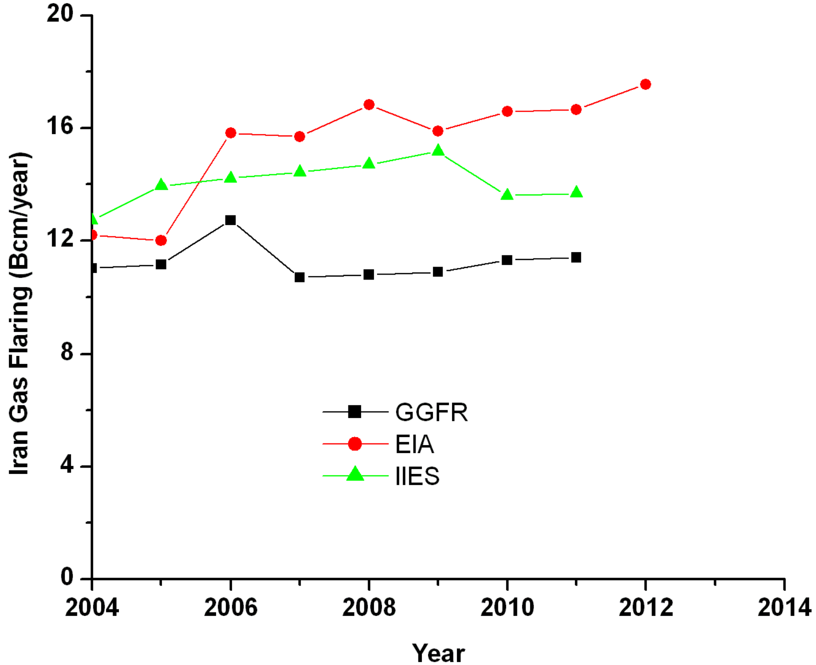
Due to economic reasons, gas collecting at offshore fields (IOOC) have been delayed, which leads to substantial higher EF and emissions than inland fields.

Company	Gas Flaring Volume (10^{12} m3)	Oil Prod. Vol. (1000 bbl/day)	Emission Factor (m^3/bbl)
National Iranian South Oil Company	12.68	2977.59	4.26
Iranian Central Oil Fields Company	3.98	159.72	24.92
Iranian Offshore Oil Company	20.35	611.39	33.28
Arvandan Oil and Gas Company	0.46	154.94	2.97

Gas Flaring In Iran

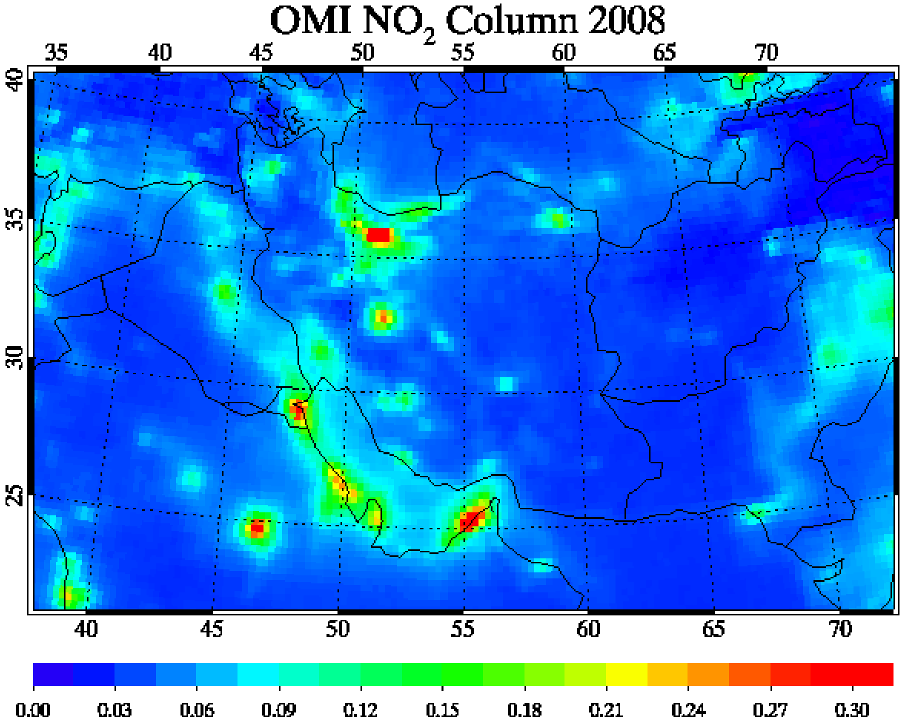
- Recent international sanctions cut the crude oil export by half since 2011 → Substantial decrease (~20%) in oil production, but the amount of gas flaring didn't change.
- The reduction of oil production due to sanctions forced Iran to extract oil from the shared offshore fields. As such, even the oil production has been cut ~20%, the total flared gas volume has not changed substantially.

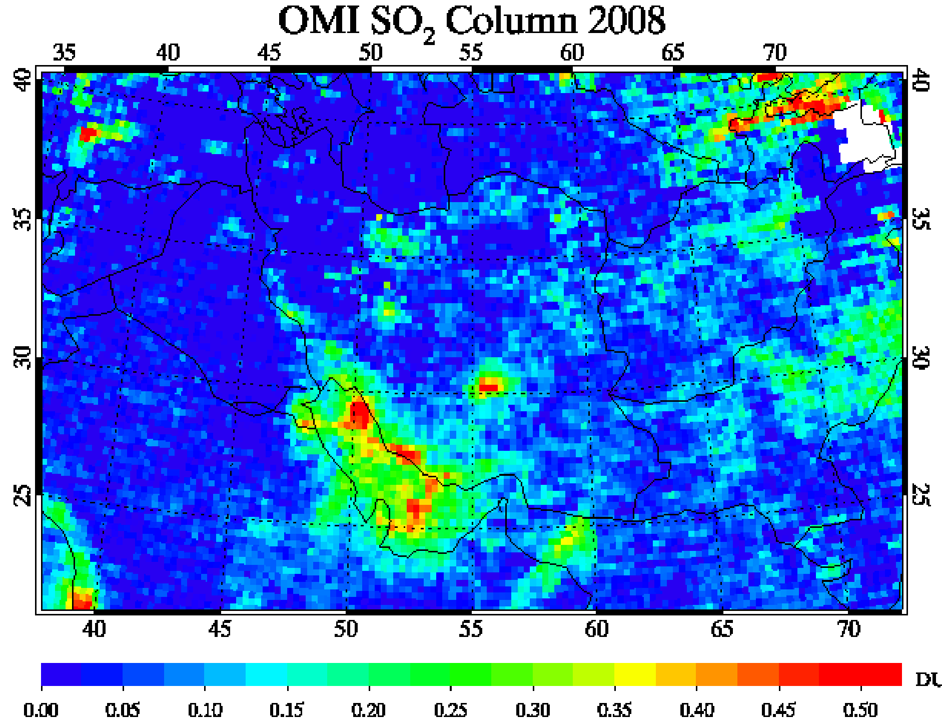




OMI observations

- Signals of gas flaring emissions from space : SO_2, NO_x, VOCs, and BC aerosols.
- Long-term OMI Level 3 products: SO_2, NO_2, HCHO, and Aerosol Index (AI).





OMI NO_2 map shows hot spots of big cities, while OMI SO_2 map show gas flaring sites

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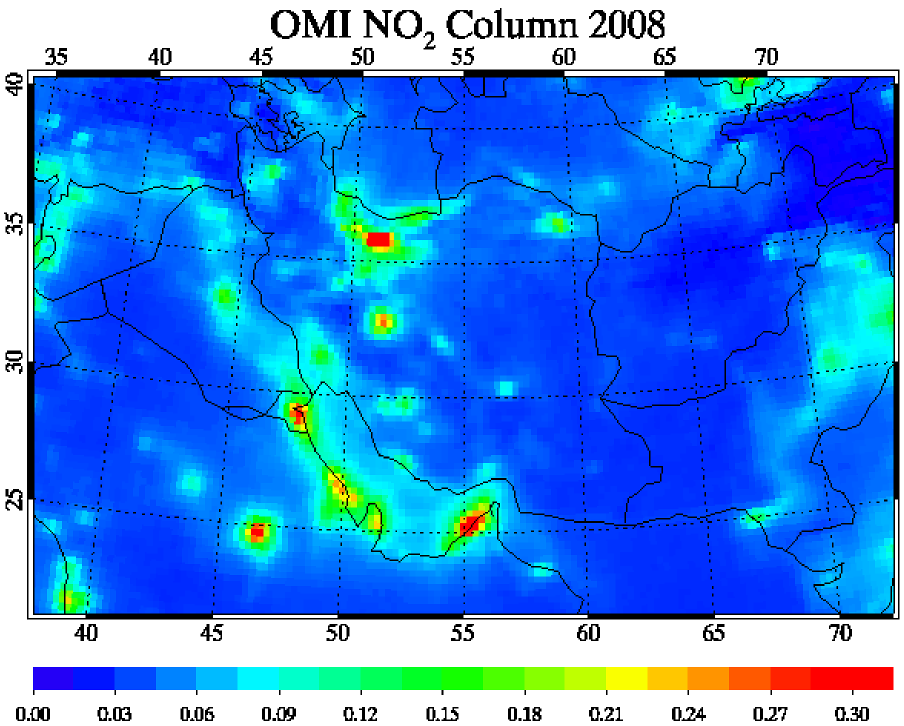

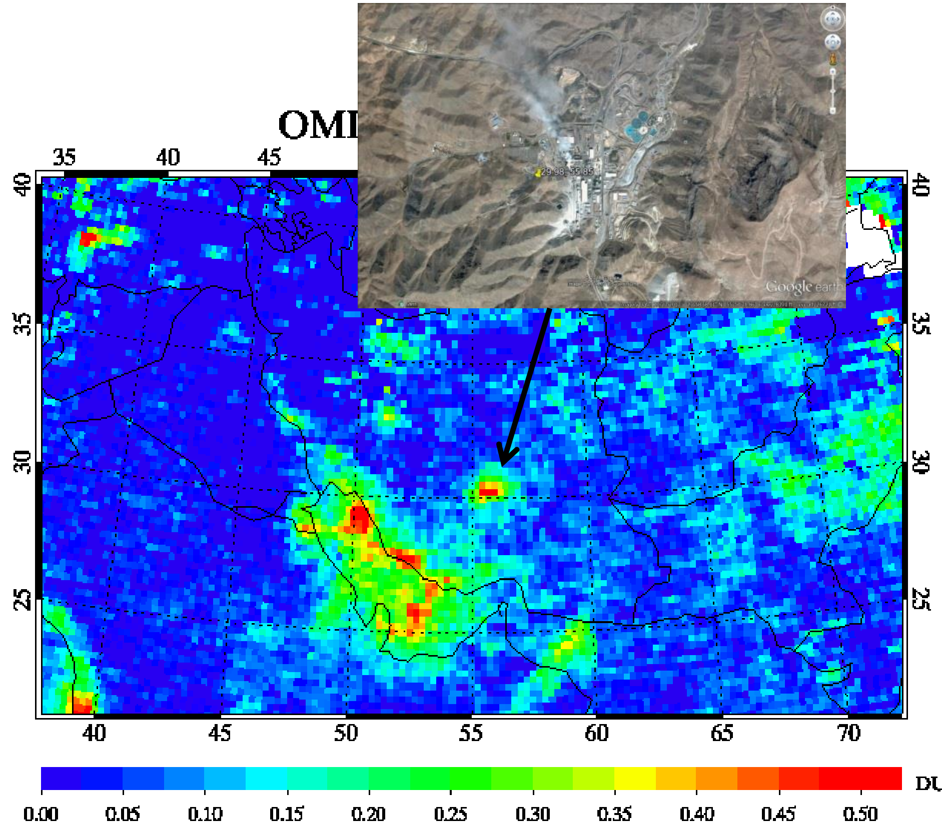

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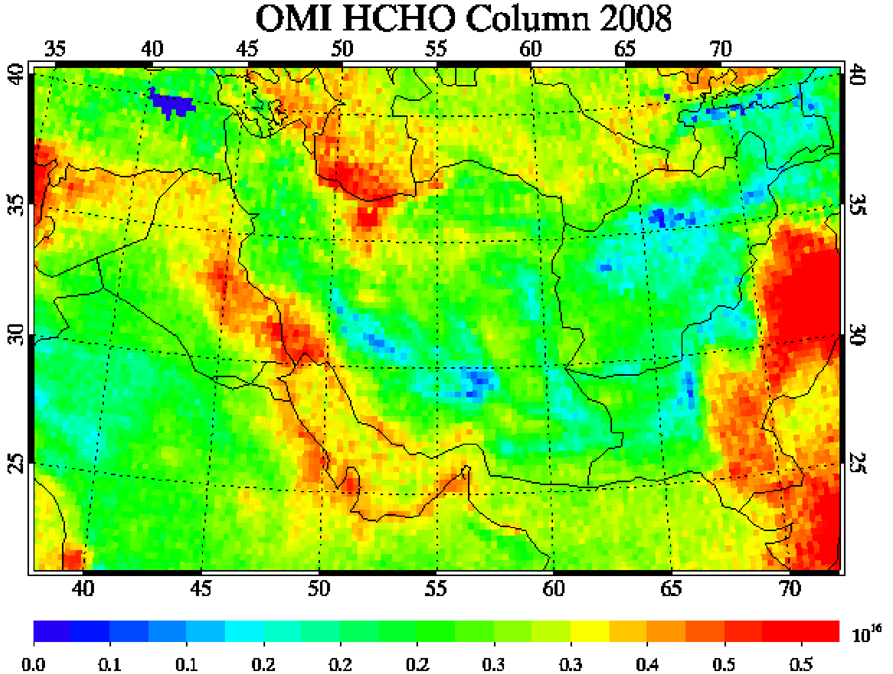
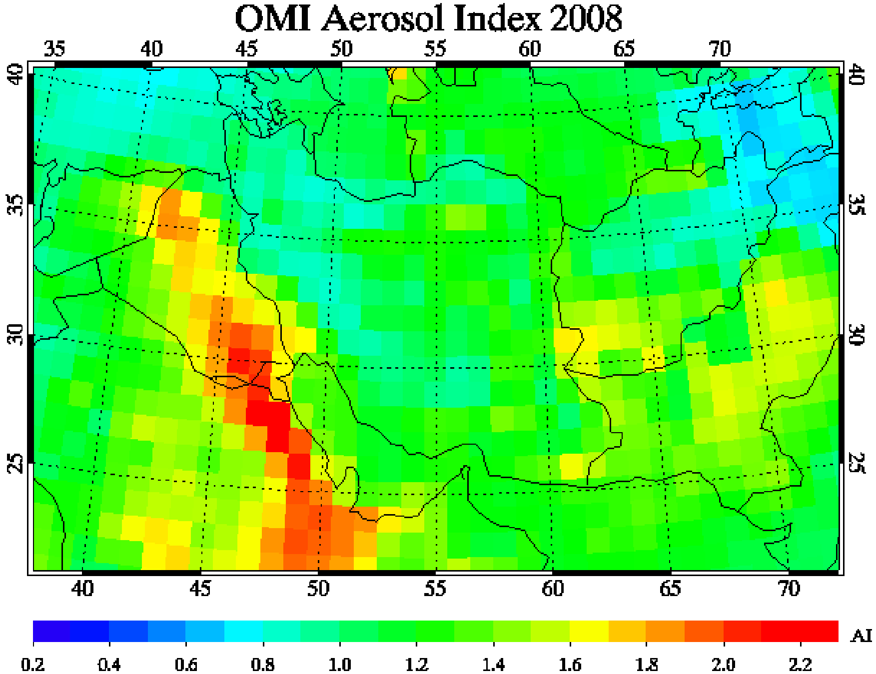




OMI HCHO map shows high values over the Persian Gulf, while OMI AI map shows weak signal for absorbing aerosol.

Case study

- Five sites are selected:
  - Khark Island: a major offshore oil production fields
  - Das Island: natural gas rig and processing (shared with Qatar)
  - Assaluyeh: the largest gas processing facility and port
  - Sarakhs: a major inland gas processing center
  - Sarcheshmeh: a large copper smelter

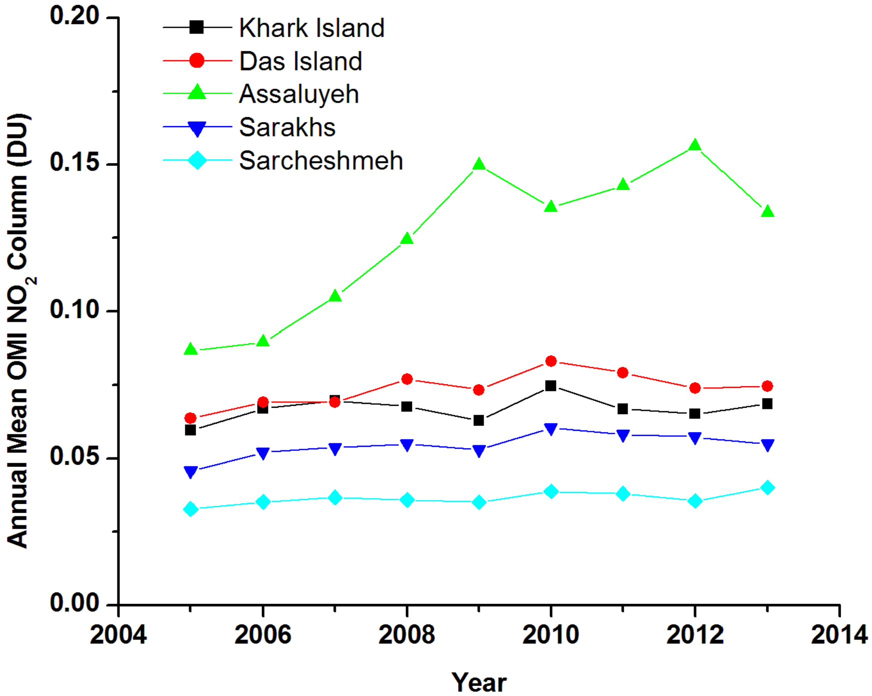
Cooper Smelter

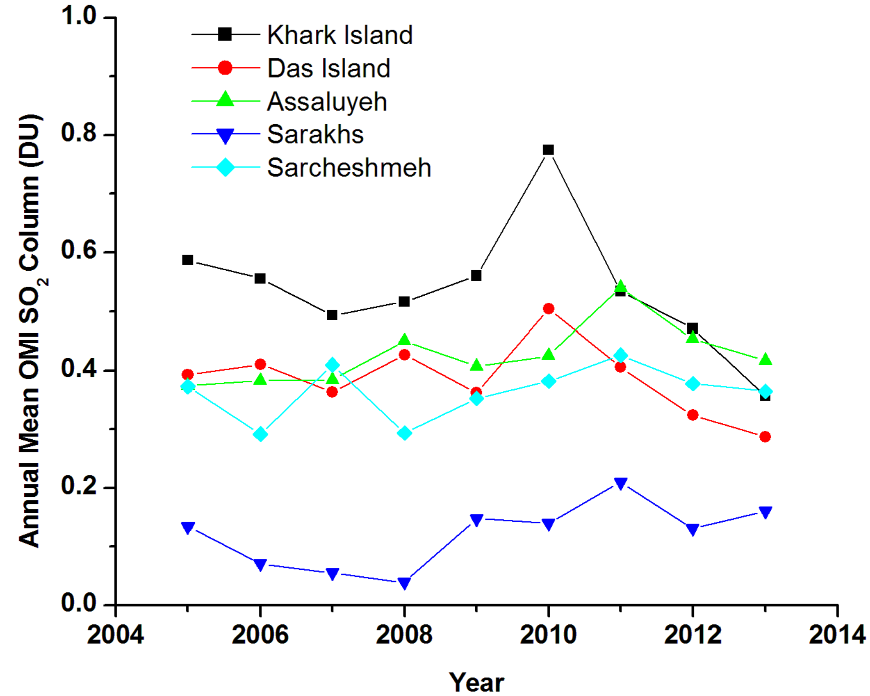
Natural Gas Facility

Natural Gas Facility (Qatar)

Natural Gas Facility/Port

Trends of OMI observations

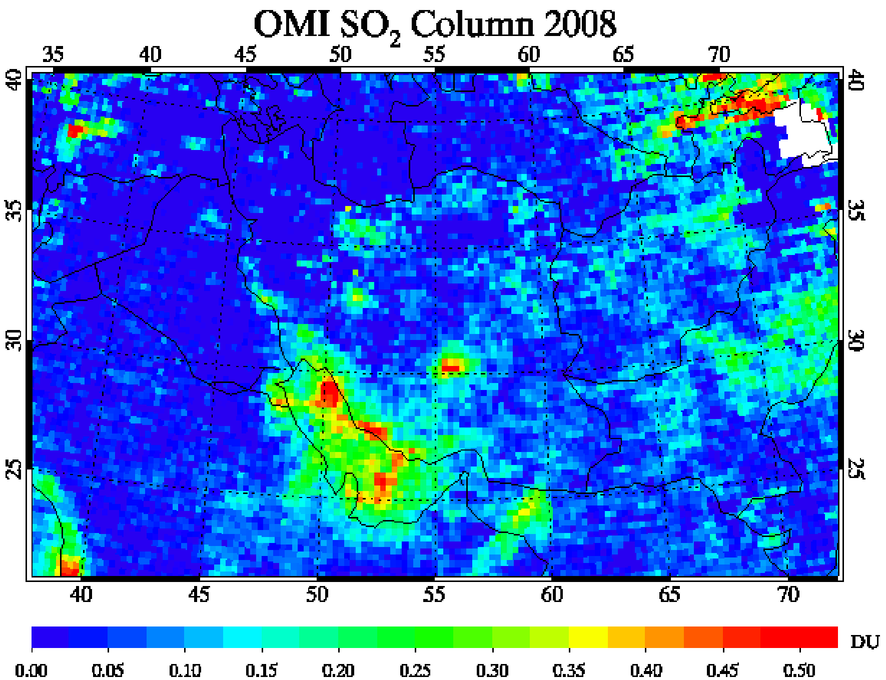


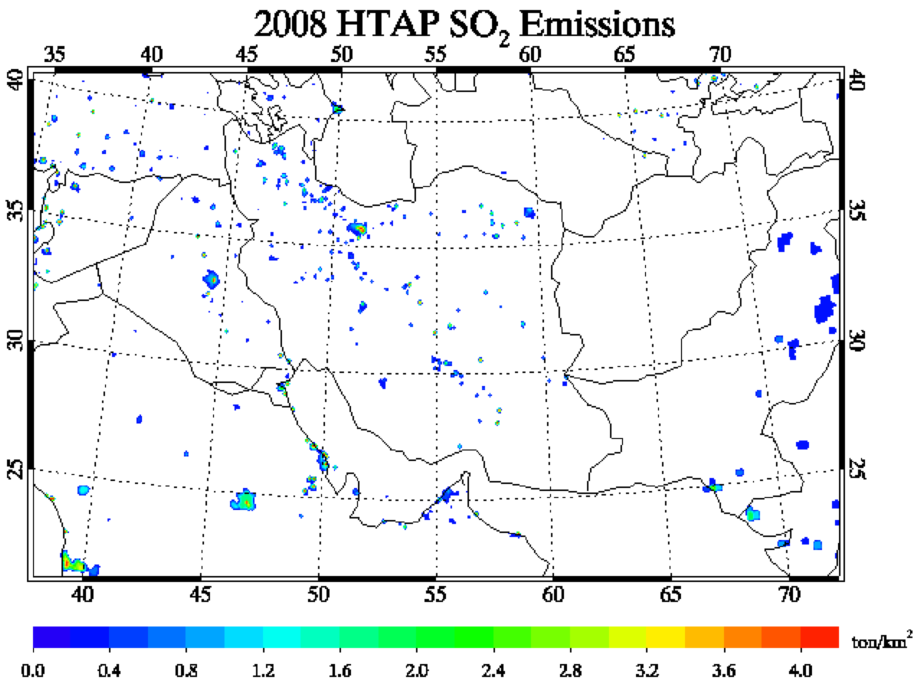


OMI NO_2 data show no big change in the past decade for flaring sites and the copper smelter, except increase around 2009 at Assaluyeh (gas facility and port).
OMI SO_2 data show no changes for Sarcheshmeh (the copper smelter) → benchmark
OMI SO_2 data show small decrease over Khark Island, and Das Island → associated with drastic changes of oil production in that field after 2010.

SO_2 Emissions from Offshore Fields

We used the 2008 EDGAR-HTAP emissions inventory to investigate the SO_2 emissions in the Persian Gulf area. Compared with the OMI SO_2 map, the offshore SO_2 emissions are missed in the current version of emission inventory.





Conclusions and Discussion

- Emissions of SO_2 are well captured by OMI, but the Global EDGAR-HTAP emission inventory underestimates SO_2 sources from offshore oil fields on the Persian Gulf.

- Recent sanction against Iran significantly decreased oil and natural gas export. OMI found that the SO_2 column over the Persian Gulf fell. No detectable changes in NO_2, HCHO, and Aerosol Index were found yet.

- In the future study, we will use the newly released version of OMI SO_2 products (PCA algorithm), which has reduced noise and unphysical biases, but greater sensitivity to emission sources. We will ratio SO_2 observations to CO retrievals to improve the emission inventory.

Acknowledgement and Selected References

- We thank Drs. G. Abad and K. Chance for providing OMI HCHO products. We appreciate the National Iranian Oil Company for providing the oil production and gas flaring data. H.H. and R.D. thank the support of Aura Science Team and NASA Air Quality Applied Science Team (AQAST). M.S. is grateful to the Department of Atmospheric and Oceanic Science of the University of Maryland for hosting his sabbatical during 2013-2014 and the financial support provided by Professor E. Kalnay. M.S is aslo thankful to Sharif University of Technology, Tehran, Iran for the permission to take this sabbatical.

- **Selected References**

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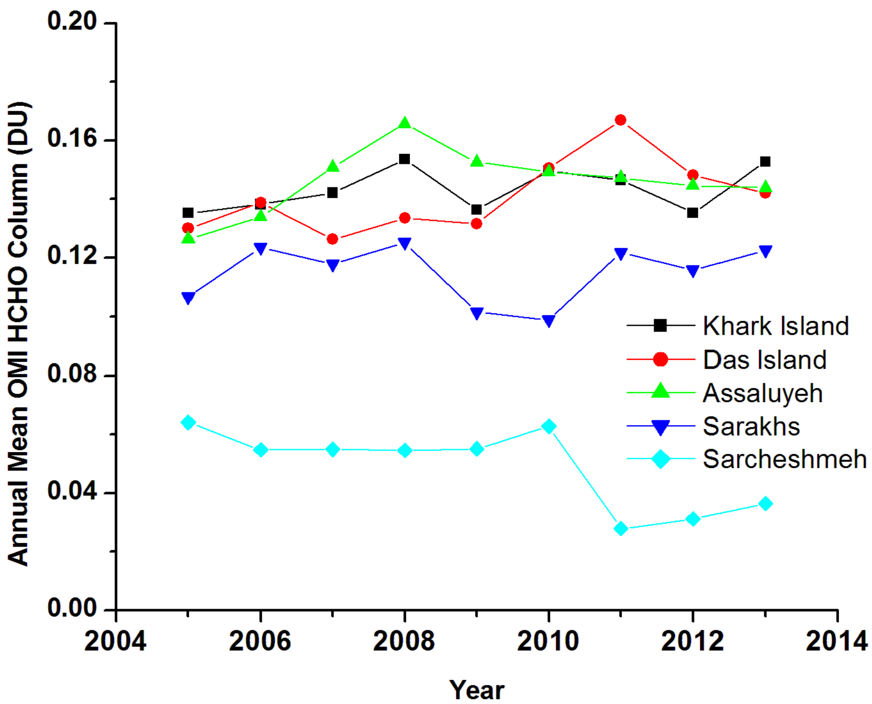
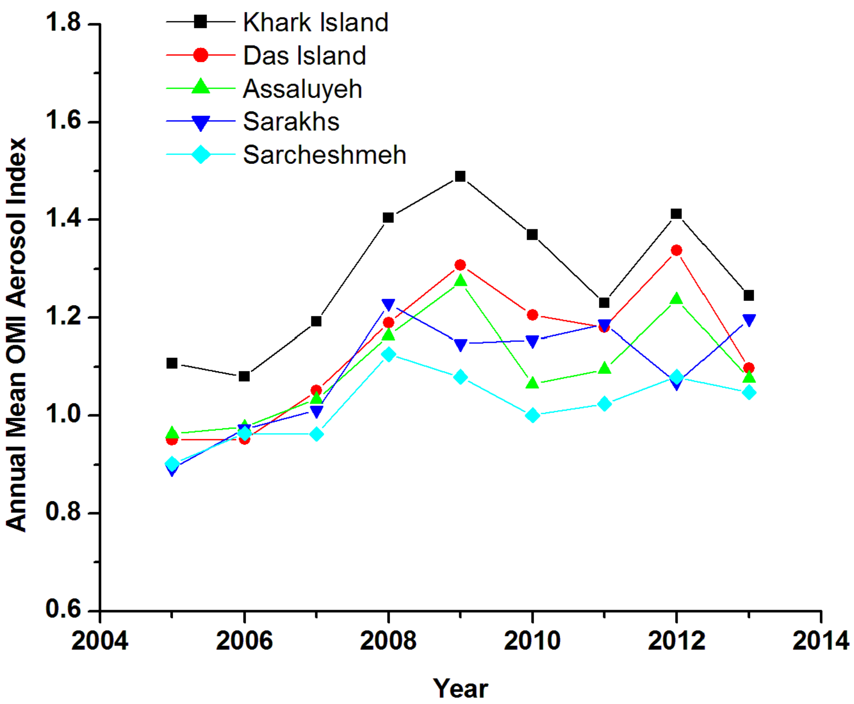
Extra Slides

Trends of OMI observations



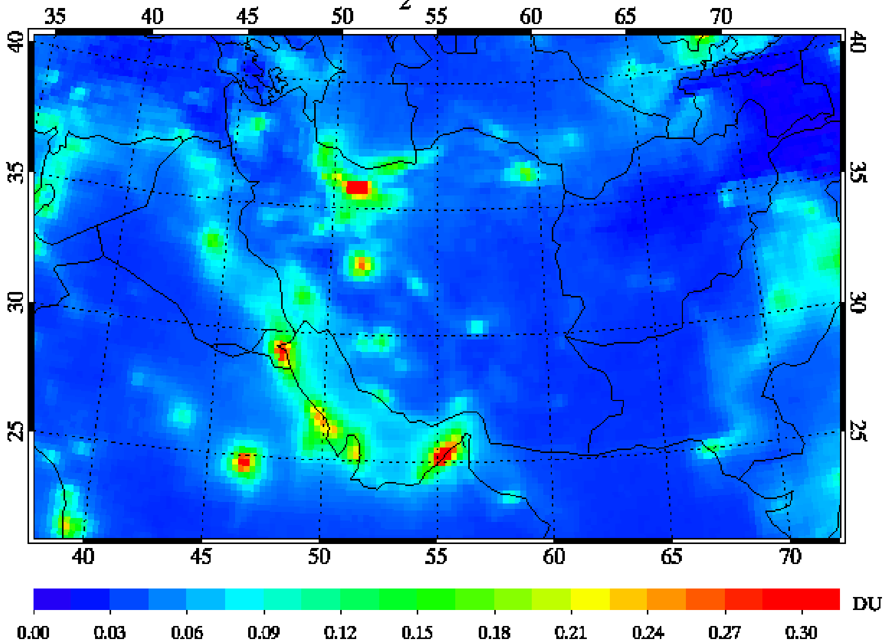


We didn’t find big changes for HCHO and AI → not a lot of HCHO and BC produced from flaring or the weak signals can not be observed in L3 data.

NO_2 Emissions in the Persian Gulf region

We used the 2008 EDGAR-HTAP emissions inventory to investigate the NO_x emissions in the Persian Gulf area. Compared with the OMI NO_2 map, the major sources of NO_2 are included in the inventory.

OMI NO_2 Column 2008



2008 HTAP NO_x Emissions